CONTINUING MEDICAL EDUCATION

Diving Medicine in Clinical Practice

Lars Eichhorn, Dieter Leyk

SUMMARY

Background: Diving is a popular sport, and some recreational divers have medical risk factors. Their health can be endangered by high extracorporeal (ambient) pressure and its many systemic effects.

Methods: We review relevant publications on free (breath-hold) diving, scuba diving, medical evaluation for diving, barotrauma, decompression sickness, and diving with medical risk factors, which were retrieved by a selective search of PubMed.

Results: Free diving or scuba diving, even at seemingly innocuous depths, puts considerable stress on the cardiovascular system, ears, and lungs. Unexpected events while diving, diminished functional reserve, and pre-existing medical illnesses increase the risk of a diving accident. An international survey revealed that minor incidents occur in 1.3% of all dives, and decompression accidents in 2 of every 10 000 dives. A properly conducted medical examination to determine diving fitness, followed by appropriate counseling, can make a life-threatening diving accident less likely.

Conclusion: To be able to certify diving fitness and give competent medical advice about diving, physicians must be well informed about the physical and physiological changes of diving and the associated risks to health, and they need to know how to perform a medical evaluation of prospective divers. In Germany, any licensed physician may judge a person fit to dive. It is recommended that this be done in adherence to the relevant evaluation standards and recommendations of the medical specialty associations. Randomized controlled trials on the effect of preventive behavior would be desirable, as would a central registry of diving accidents.

► **Cite this as:**
Eichhorn L, Leyk D: Diving medicine in clinical practice. Dtsch Arztebl Int 2015; 112: 147–58. DOI: 10.3238/arztebl.2015.0147

Department of Anesthesiology and Intensive Care Medicine, University of Bonn: Dr. med. Eichhorn

Central Institute of the German Armed Forces' Medical Service, Department IV—Military Ergonomics and Exercise Physiology—Koblenz: OTA Prof. Dr. med. Dr. Sportwiss. Leyk

Research Group Epidemiology of Performance, Institute for Physiology and Anatomy, German Sport University Cologne: Prof. Dr. med. Dr. Sportwiss. Leyk

Recreational diving has been very popular for decades (1). It is not commonly thought of as a strenuous sport, as the body is weightless under water and the required exertion is typically only mild (2). Nonetheless, major physiological stress can arise rapidly through unforeseeable environmental changes (currents, waves, underwater animals), the increasing respiratory resistance of the diving regulator at increasing depths, and/or emotional factors (3–6). One must always remember that diving can be dangerous even at seemingly innocuous depths. High extracorporeal (ambient) pressure can seriously affect the diver's health. A medical evaluation for fitness to dive is a prerequisite for diving at any domestic or foreign dive center. To evaluate and advise prospective divers competently, physicians must possess a thorough knowledge of the physical and physiological aspects of diving, the associated risks to health, and the criteria for declaring a person unfit to dive.

Methods

PubMed searches carried out on 30 June 2014 with the search terms "scuba diving," "decompression sickness," "decompression sickness diving," and "risk factors decompression sickness" retrieved 939, 3387, 1597, and 294 publications, respectively. Further searches on "foramen ovale diving" yielded 101 hits; "body fat index scuba diving," 2; "diving barotrauma tooth," 24; "decompression sickness dehydration," 18; "breath hold divers," 223; "scuba ear," 454; "scuba eye," 23; and "diving guidelines," 106. Publications were selected for inclusion in this review on the basis of their relevance, methods (statistical techniques and values), and citations in the specialized literature.

Learning objectives

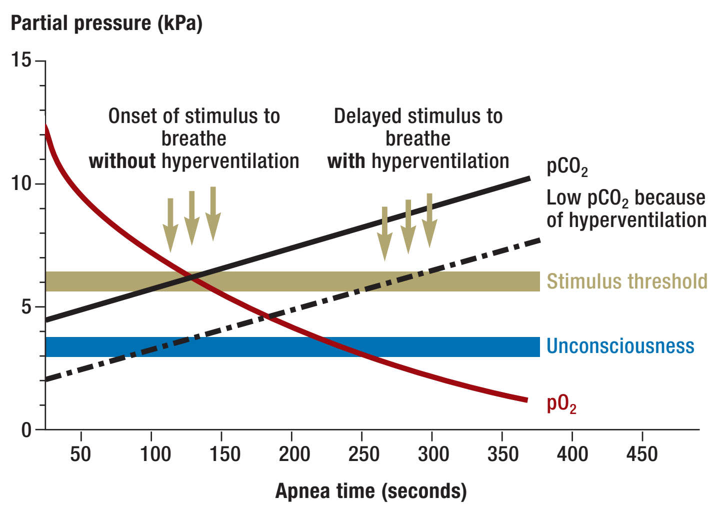
This article provides readers with information on:

- basic physical and physiological aspects of diving

Prerequisite for diving

A medical evaluation for fitness to dive is a prerequisite for diving at any domestic or foreign dive center.

FIGURE 1



Delayed stimulus to breathe after hyperventilation

- the elements of a complete diving fitness examination and appropriate counseling
- the classification and proper management of diving accidents.

Basic physical and physiological aspects

Apnea and respiratory drive

The two types of diving are device-assisted diving with a scuba set (from the acronym SCUBA, for "self-contained underwater breathing apparatus") and free diving (breath-hold diving, apnea diving). Normal persons can hold their breath for 30 to 90 seconds; trained breath-holders can remain under water for more than 6 minutes (world records: 11:35 minutes ♂, 9:02 minutes ♀). The main factors affecting the longest tolerated duration of apnea are lung volume, O_2 consumption rate, and CO_2 tolerance (e1). Hyperventilation just before diving lowers the arterial partial pressure of CO_2 and thereby delays the reappearance of the stimulus to breathe, which typically occurs when the pCO_2 rises to 45–60 mmHg (e2). Hyperventilation also mildly raises the alveolar O_2 concentration and, with it, the arterial pO_2 (e3), but this cannot compensate for the O_2 deficiency arising toward the end of the dive. Once the individual's O_2 reserve has been used up, a lack of respiratory drive can lead to loss of consciousness (shallow-water blackout) *(Figure 1)*. In deep-water free diving, the pO_2 is further lowered in the ascent phase by the decreasing ambient pressure. Even if the diver did not hyperventilate before the dive, hypoxia can develop, leading to loss of consciousness, typically in the last few meters below the surface (ascent blackout; in English, often misleadingly termed deep-water blackout) (e4, e5).

Pressure-volume changes in diving

In both free diving and scuba diving, even small changes of depth lead to major changes in pressure, owing to the high density of water. For every additional 10 m of depth under water, the ambient pressure rises by 1 bar (roughly 750 mmHg, near the typical atmospheric pressure on Earth at sea level). Thus, at a depth of 20 m, the pressure is 3 bar (1 bar atmospheric pressure plus 1 bar for every 10 m of depth). If a diver descends to 10 m in a free dive, Boyle's Law (pressure × volume = constant) implies that the volume of air in his or her lungs is halved. The theoretical depth limit for free diving is reached when pressure changes can no longer be compensated for by reduction of pulmonary volume; in other words, the theoretical maximum ambient pressure, in bar, equals the total capacity divided by the residual volume. Moreover, when the body is immersed in water, gravity no longer induces pooling of blood in the lower limbs, and there is therefore a net shift of blood into the central regions. Additional blood in the pulmonary circulation takes up some of the volume normally occupied by alveolar air; this lowers the residual volume and thereby extends the depth limit (7, 8). The effect is increased if the pressure in the alveoli is lowered, according to Boyle's Law.

Depth records in free diving—Diving depths beyond the calculated limits (world record 214 m ♂, 160 m ♀) can be achieved with the aid of special breathing techniques ("mouthfill," "packing"), which, however, can cause cardiac syncope, barotrauma, and pulmonary edema (9–11).

Scuba diving—The demand-valve regulator used in scuba diving supplies the diver with air for breathing at a pressure corresponding to the ambient pressure at any depth. Pressure differences arising in the descent and ascent phases are eliminated when the diver breathes. If the diver inappropriately holds his or her breath and ascends with the lungs full of air, the ensuing difference

Physical and physiological changes

- Diving causes marked physical and physiological changes.
- High ambient pressure can severely impair a diver's health.

Complications related to diving technique

- Free divers may suffer a loss of consciousness (shallow-water blackout or ascent blackout).
- Breath-holding during the ascent phase can cause severe barotrauma.

TABLE 1

Contraindications to diving (grouped by organ system)

Relative contraindications	Absolute contraindications
Ears	
– Incipient otitis externa – Incomplete auditory canal stenosis – Chronic dysfunction of Eustachian tube with impaired Valsalva maneuver – Radical cavity formation without dizziness or falling tendency on cold caloric testing	– Marked swelling of auditory canal – Complete auditory canal stenosis – Acute dysfunction of Eustachian tube so that pressure equalization by Valsalva maneuver is not possible – Radical cavity formation with dizziness and falling tendency on cold caloric testing – Perforated eardrum; unstable atrophic scarring of eardrum; tympanic drainage (may be possible with a special diving mask that protects the ears from contact with water) – History of acute hearing loss (with vestibular manifestations; acute phase of hearing loss, acute phase of tinnitus)
Lungs	
– Well-controlled asthma with or without medications (with stable pulmonary function) – Chronic bronchitis without obstruction – Secondary pneumothorax with unremarkable chest CT and normal pulmonary function tests	– Poorly controlled asthma – Acute exacerbation, stress- and/or cold-induced asthma – COPD with impaired pulmonary function FEV_1/FVC <70% and FEV_1 <80% of norm – Acute exacerbation, pulmonary emphysema, acute bronchitis – Pulmonary cysts/bullae, bronchiectasis
Heart	
– >1 year after ACS with normal cardiac reserve and good ventricular function – Chronic atrial fibrillation with good rate control and normal exercise tolerance (without any limiting underlying disease) – Pre-excitation syndromes – Stage I valvular disease or status post valve surgery with normal hemodynamics and exercise tolerance (echocardiography and long-term ECG!) – Atrial and ventricular septal defects without hemodynamically signigicant shunting (echocardiography obligatory, preferably by the transesophageal route) – Persistent PFO: low-bubble diving recommended *(cf. Box 2)*	– <1 year after ACS; also >1 year in case of CHF, angina pectoris, arrhythmia requiring treatment, or impaired ventricular function – Tachyarrhythmia requiring treatment, with or without structural heart disease; supraventricular extrasystole with impaired consciousness; complex arrhythmias – Aortic or mitral stenosis with valve opening <1.5 cm² – Hemodynamically significant cardiac anomalies – Persistent PFO and history of DCS despite low-bubble diving

ACS, acute coronary syndrome; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CT, computed tomography; DCS, decompression sickness; ECG, electrocardiography; FEV_1, one-second capacity; FVC, forced expiratory vital capacity; PFO, patent foramen ovale

between the intrathoracic and the ambient pressure can cause pulmonary barotrauma (pneumothorax, mediastinal emphysema, and air embolism).

The solubility of gases in liquids

Gases dissolve in organic tissues to an extent that depends on the type of gas, pressure, temperature, and time. About 78% of the pressurized air that is breathed in scuba diving is nitrogen gas; nitrogen thus accounts for most of the gas that dissolves in the blood and other bodily tissues during the dive. The time course of nitrogen dissolution is exponential, with saturation half-times varying widely from one bodily compartment to another ($t_{1/2}$ = 1–18 min in the central nervous system, versus 305–635 min in the bones and joints) (12). During a dive, high partial pressures of nitrogen can exert an anesthetic effect (nitrogen narcosis, the so-called rapture of the deep). During ascent, as the ambient pressure lessens, the dissolved gases are carried via the bloodstream to the lungs and eliminated by expiration. Modern diving computers have algorithms to compute nitrogen saturation and desaturation; along with the basic parameters (depth and time), these algorithms take account of other factors, including

Gas bubbles emerging from solution

Gas bubbles emerging from solution during ascent can cause arterial gas embolism or decompression sickness.

Dehydration

Dehydration increases the risk of decompression sickness.

BOX 1

The medical evaluation for fitness to dive

- **History**
  - Past medical history
  - Current complaints
  - Physical performance ability
  - Extent of training in diving
  - Emotional state
- **Current medications**
  - Critical assessment of all drugs, especially antidepressants, decongestants, antihistamines, antiemetic drugs, anticonvulsants, sedatives, antipsychotic drugs, and stimulants
  - Beware of drugs that impair driving ability, and anticonvulsants in particular
- **Physical examination**
  - A full examination according to the examination form of the medical specialty societies (GTÜM, ÖGTH)
  - Examination of the skin and eyes
  - Otoscopic inspection of the eardrum
  - Assessment of pressure equalization by Valsalva maneuver
  - Examination of the heart, lungs, abdomen, urogenital tract, and musculoskeletal system
  - Brief neurological examination
- **Ancillary testing**
  - Rest ECG, lung function tests (VC, FEV_1, FEV_1/FVC)
  - From age 40 onward, symptom-limited stress ECG (also under age 40 if indicated by history)
  - Studies should be performed and interpreted according to the guidelines of the specialty societies
- **Additional specialized studies**
  - Further specialized testing is needed in some cases, e.g., body plethysmography or imaging studies. The ordering physician should clearly formulate the question relevant to diving that is to be answered.

VC, vital capacity; FEV_1, one-second capacity; FVC, forced expiratory vital capacity; GTÜM, German Society for Diving and Hyperbaric Medicine; ÖGHT, Austrian Society for Diving and Hyperbaric Medicine

water temperature, physical exertion, heart rate, and minute ventilation, to give the diver an individualized ascent plan. Further factors influencing nitrogen saturation and desaturation include the rate of ascent, the duration and depth of the dive, the number of dives performed in a single day, the duration of surface intervals, and the adequacy or inadequacy of fluid balance (13, 14).

Immersion diuresis—Immersion of the body in water increases venous return to the heart (e6). As a counter-regulatory measure, the cardiac atria secrete atrial natriuretic peptide (ANP), causing diuresis (the Gauer-Henry reflex) (e6). At the same time, diuresis is reinforced by the lessened secretion of antidiuretic hormone (ADH) from the posterior lobe of the hypothalamus. The ensuing reduction of blood volume protects the cardiovascular system from the (putative) volume overload. Moreover, during ascent, fluid is lost in expired air as well, because the very dry pressurized air that the diver breathes is moistened during expiration. The absolute volume deficiency changes the rheological properties of the blood and promotes the development of decompression sickness (e7). Divers should therefore take care to drink enough fluid before diving.

Medical evaluation and counseling for diving fitness

For persons in good health aged 18 to 40, the German Society for Diving and Hyperbaric Medicine (*Gesellschaft für Tauch- und Überdruckmedizin,* GTÜM) recommends a medical evaluation once every three years. Most insurance companies and dive operators require diving fitness certification. For all other persons, and for persons with certain medical problems (see, for example, the relative contraindications listed in *Table 1*), medical evaluations are required at one-year intervals (15). Any acute illness nullifies diving fitness until complete recovery. After any serious illness, surgical procedure, or diving accident, the diver should be re-evaluated by a physician trained in diving medicine.

The required elements of the diving fitness evaluation are thorough history-taking and a complete physical examination (including visual inspection of eardrum mobility), an ECG at rest, pulmonary function tests, and an assessment of physiologic reserve, typically with a bicycle ergometer (16) (for more information, see *Box 1* and the recommendations of national medical societies on recreational diving, e.g.,

The frequency of diving fitness evaluations

Evaluations should be performed at 3-year intervals from age 18 to age 40 and annually at all other ages.

The diving fitness evaluation

Among the required elements of the diving fitness evaluation are thorough history-taking and a complete physical examination.

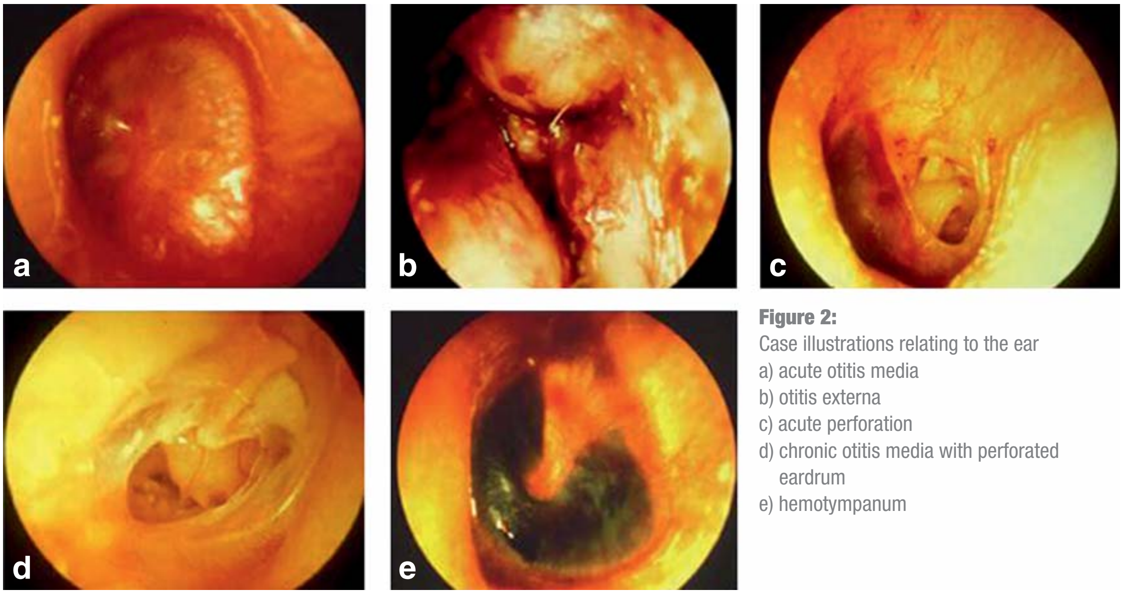


Figure 2:
Case illustrations relating to the ear
a) acute otitis media
b) otitis externa
c) acute perforation
d) chronic otitis media with perforated eardrum
e) hemotympanum

www.gtuem.org). For particular questions, a medical specialist should be consulted, preferably one with special expertise in diving medicine. More detailed information on the diving fitness evaluation, age- and sex-specific considerations (diving for children, senior citizens, and pregnant women), and diving for particular groups of persons (such as those with various types of handicap), as well as on illnesses that relatively or absolutely contraindicate recreational diving (e.g., diabetes, cardiovascular diseases), can be found (in German) in the reference work *Checkliste Tauchtauglichkeit – Untersuchungsstandards und Empfehlungen,* issued by the GTÜM *(Table 1)*.

Common reasons for medical unfitness to dive

In this section, we discuss illnesses and organ systems that are of particular relevance to medical unfitness to dive (see also Reference [10], *Box 1* [on the medical evaluation of diving fitness], and *Table 1* [on selected contraindications]).

Ears, paranasal sinuses, teeth

If the physiologic communication of the middle ear with the naso- and oropharynx is impaired by mucosal edema (e.g., because of allergies or an upper respiratory infection), pressure equalization with a Valsava maneuver may not be possible. When the individual dives, this can lead to pain, hemorrhage, or exudation and, ultimately, to eardrum perforation *(Figure 2)*. The consequences of eardrum perforation include water in the middle ear, disequilibrium because of the caloric stimulus, vomiting, disorientation, and a possible panic reaction resulting in an excessively rapid ascent (17). Impaired aeration of the middle ear or otitis media disqualifies the individual from diving *(Table 1)*. Even persons whose fitness to dive is officially only partly restricted (e.g., to diving only in a swimming pool or in shallow water) should refrain from diving, as large pressure differences in air-filled cavities arise even at seemingly innocuous depths. Moreover, the earplugs that divers often use may themselves damage the eardrum, because the air pressure cannot be equalized in the artificial cavity that they create.

Diving often impairs the local barrier function of the external auditory canal epithelium, either because it becomes too moist or because salt crystals form on it (e8, e9). The affected divers often worsen the situation by excessive cleaning of the ear with cotton swabs (which can cause microtrauma) or by rinsing it with nonprescription fluids of various kinds (oils, alcohol-based rinses). Some simple measures can help prevent such

Problems affecting the ears

Any impairment of middle-ear aeration disqualifies the individual from diving.
Rinsing the external ear with ordinary drinking water, thorough drying, and protecting the ear from the wind can help prevent otitis in divers.

Problems affecting the teeth

Air trapped under dental fillings or temporary crowns can re-expand during the diver's ascent, causing severe toothache. Divers who intend to spend long periods abroad should be advised to have a dental check-up first.

problems (rinsing the external ear with ordinary drinking water after diving, thorough drying, and protection from the wind). If the ear canal is severely irritated or swollen, diving is contraindicated.

Air trapped under dental fillings or temporary crowns can re-expand during the diver's ascent, causing severe toothache. Divers who intend to spend long periods abroad should be advised to have a dental check-up first (18).

Eyes

If the diver fails to equalize pressure inside the diving mask by exhaling through the nose during the descent, conjunctival bleeding may result (19). Divers need to see well, so that they can stay oriented, recognize dangers, and read instruments. Refractory errors can be corrected with prescription dive masks or with soft contact lenses (20). Persons who have just undergone cataract surgery should not dive until complete healing has taken place (i.e., for at least 4 weeks). Persons with a history of glaucoma should be examined by an ophthalmologist. Well-controlled open-angle glaucoma without optic nerve dysfunction is not a contraindication to diving, but persons with untreated narrow-angle glaucoma must not dive (21). Persons who have undergone refractive surgery, e.g., laser-assisted *in situ* keratomileusis (LASIK), should not dive until complete healing has taken place (this can take anywhere from 3 months to several years), and only after evaluation by an ophthalmologist (22, 23). Severe infections of any kind from which the individual has not yet fully recovered, advanced disease of the chorioretinal vasculature, and advanced macular degeneration are further absolute contraindications (24–26).

Lungs

Changes in the lungs and airways can also increase the risk of a severe diving accident. Acute infections that stimulate the production of mucus (bronchitis, colds, etc.) alter air flow in expiration and increase the risk that air trapping in the alveoli will lead to barotrauma. Persons with COPD who have impaired pulmonary function with an FEV_1/FVC ratio below 0.7, pulmonary emphysema, bullae, or an acute exacerbation are unfit to dive *(Table 1)*. Fitness to dive is harder to assess in persons with asthma (27). If they have well-controlled asthma without any symptoms, with FEV_1 and peak-flow values above 80% of the norm, they may be fit to dive. Uncontrolled or partly controlled asthma in which pulmonary function has not yet been stabilized (www.ginasthma.com) is an absolute contraindication. Persons with exercise- or cold-induced asthma should not dive, either, because their airways can easily be irritated by the cold and very dry air coming from the scuba set. Persons with a history of pulmonary injury (trauma or thoracic surgery) are generally fit to dive, as long as further pulmonary function testing (whole-body plethysmography) and pulmonary CT yield normal findings (28). Idiopathic spontaneous pneumothorax or status post pleurodesis to prevent recurrent pneumothorax are absolute contraindications to diving.

Cardiovascular system

Persons of any age with a history of cardiovascular problems (including, but not limited to, coronary heart disease [CHD], angina pectoris [AP], peripheral arterial occlusive disease [PAOD], an implanted cardiac pacemaker, hypertension, or a persistent foramen ovale [PFO]) should undergo more extensive evaluation, e.g., with long-term ECG monitoring or a stress ECG, long-term blood-pressure measurement, echocardiography, or cardiac catheterization. When indicated, they should be evaluated for fitness to dive at markedly shorter intervals than other persons. The most important criteria for diving fitness in such cases are cardiac functional reserve and hemodynamic stability. Persons who have had a heart attack but still have good ventricular function may well be fit to dive; the same holds for persons with atrial fibrillation, as long as they have normal cardiac functional reserve and rate control, but not for those with structural heart disease. Implanted pacemakers are not a contraindication, as long as the diver has normal cardiac functional reserve and the pacemaker is of a type that reliably withstands high pressure, with the manufacturer's certification of compatibility with diving. On the other hand, implantable cardioverter defibrillators (ICDs) and biventricular pacemakers are a contraindication, both because of the underlying disease and because of the danger of hemodynamically significant arrhythmia leading to syncope or hypertensive pulmonary edema.

Persons with essential hypertension that has been well controlled with medication for at least three months are, in general, fit to dive. Careful consideration should, however, be given to the potential adverse effects of antihypertensive drugs (for example, in persons taking beta-blockers, the diving reflex can

Ocular changes

Persons who have just undergone cataract surgery should not dive until completely healed (i.e., for at least 4 weeks). Persons with a history of glaucoma should be examined by an ophthalmologist.

Pulmonary function

Asymptomatic persons with well-controlled asthma may be fit to dive. Uncontrolled or partly controlled asthma with unstable pulmonary function is an absolute contraindication.

TABLE 2

Diving-associated incidents (classification according to the guideline for diving accidents, AWMF reg. no. 072:001)

Description and clinical manifestations		Treatment
Decompression sickness		
Pathogenesis	– Gases go into solution as the ambient pressure rises during descent (Henry's Law of gases). – The ambient pressure rises again during ascent. – If more gas comes out of solution than can be rapidly breathed off, gas bubbles form which can embolize via the arteries, causing tissue hypoxia.	
Mild form	– Marked fatigue – Cutaneous itching – Complete recovery within 30 min of institution of specific first-aid measures	– Immediate adminstration of 100% O_2 – Oral fluid administration (500 to 1000 mL) – Documentation, neurological examination, consultation with a physician trained in diving medicine, observation for 24 hr
Severe form (may arise up to 48 hours after diving)	**Peripheral manifestations:** – Cutaneous lesions, pain, paresthesiae, numbness, paresis, shortness of breath – Persistence of mild symptoms beyond 30 min despite administration of 100% O_2 and fluids **Central nervous manifestations:** – Impaired vision, hearing, and speech; dizziness, migraine attacks, nausea, impaired consciousness, loss of consciousness	– Symptomatic treatment according to the ERC guidline and administration of 100% O_2 (regardless of the gas mix used during the dive); alert the emergency rescue services with the phrase, "suspected diving accident" – Continued O_2 administration during transport to a center where pressure-chamber treatment is available (if initially not possible, transport to nearest hospital emergency room, consultation with diving physician, and secondary transfer)
Triggers	– Hypovolemia, altered perfusion (e.g., after a hot shower and/or physical exercise after the dive), diminished ambient pressure favoring emergence of gas from solution (airplane flight, driving over mountain passes, etc.), acute infection, fever, stress, fatigue, alcohol consumption, persistent patent foramen ovale	
In case of uncertainty	– Symptoms arising up to 48 hours after diving are always suspect	– Check vital parameters, monitor closely, observe symptoms and signs
Arterial gas embolism (AGE)		
Pathogenesis	– Lung injury due to volume expansion (Boyle's law) – If a pulmonary vessel is injured as well, arterial gas embolism can occur	
Manifestations	**Dramatic:** – Cardiovascular disturbances (up to and including cardiac arrest), hemiplegia/paraplegia, loss of consciousness – Symptoms often occur as early as during ascent **Possible additional findings:** – Pneumothorax, mediastinal emphysema	– Symptomatic treatment according to the ERC guidline and administration of 100% O_2 (regardless of the gas mix used during the dive); alert the emergency rescue services with the phrase, "suspected diving accident" – Continued O_2 administration during transport to a center where pressure-chamber treatment is available (if initially not possible, transport to nearest hospital emergency room, consultation with diving physician, and secondary transfer)
Triggers	– May occur despite seemingly harmless duration/depth of dive – Often triggered by excessively rapid ascent (e.g., emergency ascent)	

ERC, European Resuscitation Council; current guideline on diving accidents (www.gtuem.org)

Telephone consultation with a diving physician (in Germany): German Navy Medical Department, +49 (0) 431 – 54 09 0.
International DAN hotline, +39 06 42 11 86 85; from Germany or Austria, +49 (0) 431 – 54 09 0.
Diving hotline of aqua med, +49 (0) 700 – 34 83 54 63; VDST hotline: +49 (0) 180 – 33 22 10 5.

Mild decompression sickness

- Marked fatigue
- Cutaneous itching
- Complete recovery within 30 minutes after specific first-aid measures are provided

Severe decompression sickness

- Skin mottling or rash, pain, numbness
- Paresis, pain, shortness of breath
- Impaired vision, hearing, speech
- Dizziness, migraine attacks, nausea, impaired consciousness, loss of consciousness

BOX 2

Recommendations for "low bubble diving"*

- Start the dive by diving as deep as possible
- No yo-yo dives (no repetitive ascents in the 10 m range)
- Ascend as slowly as possible over the last 10 m
- Take a safety stop at a depth of 3 to 5 m for at least 5–10 minutes
- Don't push the time limits and don't take decompression dives
- Wait at least 4 hours before diving again
- Take a maximum of 2 dives per day
- Wait at least 2 hours before going up to a higher altitude on dry land
- Avoid warming the skin after diving (sun-bathing, sauna, etc.)
- Avoid cold, dehydration, and smoking
- Dive with Nitrox (nitrogen-enriched air for breathing) according to air tables (avoid O_2 toxicity)
- Set the safety level of the diving computer conservatively
- No exertion in the last 10 m of the ascent (avoid physical work and strong currents at the end of the dive)
- No exertion in the first 2 hours after the dive; do not carry heavy diving equipment or inflate the buoyancy vest orally after coming up from the dive (this can open a persistent patent foramen ovale through pressure differences in the heart)
- Absolutely no diving when you have a cold (coughing or forced pressure equalization promotes bubble formation)

* modified from (e13)

cause a bradyarrhythmia). Moreover, recent studies have shown that prolonged breath-holding can elevate the blood pressure (29–31). Free diving is therefore not a suitable substitute for scuba diving in persons who have been judged unfit for it.

Medical counseling about diving

A medical consultation about fitness to dive comprises not just a thorough evaluation, but also appropriate patient counseling in the light of the findings. One of the main things for prospective divers to understand is that acute illnesses of any kind, even if they seem trivial (such as an ordinary cold), are incompatible with diving. Physicians should also advise prospective divers to inform themselves of the available emergency rescue services before diving, so that no time is wasted in an emergency. This is particularly important in so-called private diving, i.e., diving on one's own, independently of any dive center.

Persons planning a diving vacation abroad should be advised that they may be unfit to fly after diving, depending on the frequency and duration of their dives. Likewise, they may be unfit to drive over mountain passes. Reduced air pressure can cause nitrogen dissolved in the blood and tissues to come out of solution, leading to symptomatic decompression sickness. Modern diving computers display the no-fly time after each dive. As a rule, the Divers Alert Network (DAN) Europe recommends not flying for at least twelve hours after single dives without a decompression stop, and for at least 24 hours after all other dives (i.e., whenever a person has dived more than once in a day or has taken a decompression stop). Moreover, divers should be advised

Cardiologic prerequisites for diving

- Adequate hemodynamic stability and functional reserve of the cardiovascular system
- Well-controlled hypertension is compatible with diving

Travel recommendations

- No flying, or driving over mountain passes, within 24 hours of the last dive
- Critical assessment of every drug the diver is taking for compatibility with diving (e.g., malaria prophylaxis)

to drink adequate amounts of fluids, as dehydration increases the risk of decompression accidents even if the dive profile is not unusual in any way.

All drugs that the prospective diver is taking should be critically evaluated for compatibility with diving; particular attention should be paid to diuretics, anti-allergic drugs, nasal decongestants, antiemetic drugs, and antimalarial drugs (32, 33) *(Box 1)*. Many of these drugs are sedating, have neuropsychiatric side effects, impair pupillary accommodation in bright light, and/or promote the development of nitrogen narcosis (34, 35).

Medical emergencies in diving

Medical emergencies in diving are rare, but sometimes life-threatening (36). They can occur wherever people dive, not just in areas of diving tourism.

The frequency of accidents

Accurate statistics on diving accidents are hard to obtain, as there is no central registry to which diving accidents must be reported. The published accident counts are often derived from treating physicians' reports; thus we must assume that far more accidents take place than have been documented. Moreover, patients with clinically diagnosed decompression symptoms are often not followed up. Data on long-term outcome is therefore rare. The diving accident report of the German Recreational Divers' Association (*Verband deutscher Sporttaucher,* VDST) for the years 2007–2013 contains an evaluation of 319 accidents in Germany (accounting for half of the total) and abroad. 37 of these accidents were fatal. The cause of death could be determined in 27:

- 13 divers died because of an internal disease,
- 7 because of a technical defect,
- and 7 because of negligence.

Likewise, data obtained internationally by the Divers Alert Network (DAN) provide evidence of the degree of risk associated with the sport. 1081 divers, questioned on a total of 14 931 dives, reported minor incidents (e.g., buoyancy control problems, excessively rapid ascent) in 1.3% (e10). Decompression accidents arose in approximately 2 per 10 000 dives. More than 40% of the divers surveyed said they had at least one chronic disease. According to a meta-analysis of DAN accident statistics for the years 2000 to 2006 (e11), the likelihood of a diving accident causing cardiac death is 12.9 times higher in divers over age 50. The available data are inadequate; a central registry for diving accidents would be desirable.

Decompression sickness

Decompression sickness is a diving emergency that can occur anywhere, even in Germany. Since the turn of the 21st century, it has been possible to dive to depths of 20 meters and more, in warm water, in indoor diving centers. Thus, decompression sickness should be thought of whenever divers develop suggestive manifestations, even if they have "only" been diving indoors *(Table 2)*. A distinction should be drawn between decompression sickness in the proper sense of the term and arterial gas embolism.

Decompression sickness is due to gas (generally nitrogen) emerging from solution in the blood or solid tissues during ascent (37). If more gas comes out of solution than can be rapidly breathed off, gas bubbles form. Small numbers of gas bubbles form in practically every dive but are generally eliminated via the lungs without further problems. When the amount of nitrogen dissolved exceeds a critical value, bubbles form and cause decompression sickness *(Table 2)*. The risk of decompression sickness is higher in divers with a persistent patent foramen ovale (PFO) (38, 39). In general, the risk of decompression sickness can be minimized by ascending slowly and prolonging the overall time of ascent (40), by taking breaks (so-called deep stops) during ascent (e12), and by adhering to the safety rules for the prevention of bubble formation *(Box 2)*.

Arterial gas embolism (AGE) can be a feature of severe decompression sickness. Another mechanism by which AGE arises in a rapid (emergency) ascent is central pulmonary tearing leading to the entry of alveolar air into the pulmonary veins, and hence into the arterial circulation, causing paradoxical embolism. The air bubbles functionally occlude the terminal arteries to which they embolize (most significantly, in the brain and spinal cord). The symptoms arise either during ascent or soon after the diver has reached the surface. They resemble those of decompression sickness but arise more rapidly and are more narrowly restricted to the central nervous system.

Divers with suspected decompression sickness should be given 100% O_2 at once, and the emergency rescue services should be alerted. Pressure-chamber treatment for emergency recompression is not available everywhere in Germany; thus, in an emergency, the patient should be taken to the nearest hospital, which must then organize secondary retransfer to the appropriate center as rapidly as possible. Expert medical advice should also be obtained in

Decompression sickness

Decompression sickness is a serious disease.

The treatment of decompression sickness

Divers with suspected decompression sickness should be given 100% O_2 at once, and the emergency rescue services should be alerted.

any diving accident (see *Table 2* for the availability of advice over the telephone from diving medicine specialists).

Further recommendations for the management of diving accidents are listed in the relevant GTÜM guidelines (www.gtuem.org).

Overview

In Germany, any licensed physician is allowed to attest a prospective diver's fitness to dive. The medical specialty associations have issued recommendations about the nature and extent of the medical evaluation that should be performed. Even though recreational diving is generally perceived by the public as a sport that does not demand much physical exertion, and that only rarely gives rise to accidents, it nonetheless carries significant risks. All prospective divers, and especially persons with medical risk factors, should be properly evaluated and counseled before their fitness to dive is attested. The expertise of diving physicians and specialists should be called upon whenever problematic findings are obtained. It is recommended that physicians attesting diving fitness should adhere to the evaluation standards and recommendations of the GTÜM, and that they should obtain GTÜM certification by passing the two relevant courses that the association offers, "Medical Evaluation for Diving" (*Tauchmedizinische Untersuchungen,* GTÜM Course I) and "The Diving Physician Course" (*Taucherarzt,* GTÜM Course IIa).

Acknowledgement
The authors thank Prof. Dr. med. Dr. h.c. Friedrich Bootz (otorhinolarnygology department, Universitätsklinikum Bonn) for kindly providing us with photographic material; Dr. med. Karin Hasmiller (president of the GTÜM), Dr. sportwiss. Uwe Hoffmann (Deutsche Sporthochschule Köln) and PD Dr. med. Björn Jüttner (department of anesthesiology and intensive care medicine, Medizinische Hochschule Hannover) for valuable information; Dr. med. Dirk Michaelis (Druckkammerzentrum Wiesbaden) for advice on the case illustration; and Dr. med. Heike Gattermann (VDST board of directors, medicine) for the VDST accident statistics.

Conflict of interest statement
Prof. Dr. med. Dr. Sportwiss. Dieter Leyk and Dr. med. Lars Eichhorn declare that no conflict of interest exists. Dr. Eichhorn is the recipient of a scholarship from the Else-Kröner-Fresenius-Stiftung.

Manuscript received on 4 August 2014, revised version accepted on 30 October 2014.

Translated from the original German by Ethan Taub, M.D.

REFERENCES

1. Anzahl der Personen in Deutschland, die in der Freizeit Tauchen gehen, nach Häufigkeit von 2012 bis 2014 (in Millionen). http://de.statista.com/statistik/daten/studie/171152/umfrage/haeufigkeit-von-tauchen-in-der-freizeit/ (last accessed on 13 October 2014).
2. Buzzacott P, Pollock NW, Rosenberg M: Diving exercise intensity inferred from air consumption during recreational scuba diving. Hyperb Med 2014; 44: 74–8.
3. Anegg U, Dietmaier G, Maier A, et al.: Stress-induced hormonal and mood responses in scuba divers: a field study. Life Sci 2002; 70: 2721–34.
4. McLellan TM, Wright HE, Rhind SG, Cameron BA, Eaton DJ: Hyperbaric stress in divers and non-divers: neuroendocrine and psychomotor responses. Undersea Hyperb Med 2010; 37: 219–31.
5. Carturan D, Boussuges A, Vanuxem P, Bar-Hen A, Burnet H, Gardette B: Ascent rate, age, maximal oxygen uptake, adiposity, and circulating venous bubbles after diving. J Appl Physiol 2002; 93: 1349–56.
6. Bove AA: The cardiovascular system and diving risk. Undersea Hyperb Med 2011; 38: 261–9.
7. Arborelius M, Ballidin UI, Lilja B, Lundgren CEG: Hemodynamic changes in man during immersion with the head above water. Aerosp Med 1972; 43: 592–8.
8. Schaefer KE, Allison RD, Dougherty JH Jr, et al.: Pulmonary and circulatory adjustments determining the limits of depths in breathhold diving. Science 1968; 162: 1020–3.
9. Lindholm P, Ekborn A, Oberg D, Gennser M: Pulmonary edema and hemoptysis after breath-hold diving at residual volume. J Appl Physiol 2008; 104: 912–7.
10. Muth CM, Ehrmann U, Radermacher P: Physiological and clinical aspects of apnea diving. Clin Chest Med 2005; 26: 381–94.
11. Dujic Z, Breskovic T: Impact of breath holding on cardiovascular respiratory and cerebrovascular health. Sports Med 2012; 42: 459–72.
12. Bühlmann AA: Computation of low-risk compression. Computation model and results of experimental decompression research. Schweiz Med Wochenschr 1988; 118: 185–97.
13. Fahlman A, Dromsky DM: Dehydration effects on the risk of severe decompression sickness in a swine model. Aviat Space Environ Med 2006; 77: 102–6.
14. Beckett A, Kordick MF: Risk factors for dive injury: a survey study. Res Sports Med 2007; 15: 201–11.
15. Empfehlung zum Untersuchungsintervall. In: Gesellschaft für Tauch- und Überdruckmedizin (GTÜM) e.V. und Österreichische Gesellschaft für Tauch- und Hyperbarmedizin (eds): Checkliste Tauchtauglichkeit. Stuttgart: Gentner 2014; 32.
16. Fletcher GF, Ades PA, Kligfield P, et al.: Exercise standards for testing and training: a scientific statement from the American Heart Association. Circulation 2013; 128: 873–934.
17. Azizi MH: Ear disorders in scuba divers. Int J Occup Environ Med 2011; 2: 20–6.
18. Zadik Y, Drucker S: Diving dentistry: a review of the dental implications of scuba diving. Aust Dent J 2011; 56: 265–71.
19. Senn P, Helfenstein U, Senn ML, Schmid MK, Schipper I: Ocular barostress and barotrauma. A study of 15 scuba divers. Klin Monbl Augenheilkd 2001; 218: 232–6; discussion 237–8.
20. Brown MS, Siegel IM: Cornea-contact lens interaction in the aquatic environment. CLAO J 1997; 23: 237–42.
21. Schnell D: Augen. In: Klingmann C, Tetzlaff K (eds.): Moderne Tauchmedizin – Handbuch für Tauchlehrer, Taucher und Ärzte. 2nd edition. Stuttgart: Gentner-Verlag 2012; 483–506.

22. Kalthoff H, John S: Intraocular pressure in snorkling and diving. Klin Monbl Augenheilkd 1976; 168: 253–7.
23. Huang ET, Twa MD, Schanzlin DJ, van Hoesen KB, Hill M, Langdorf MI: Refractive change in response to acute hyperbaric stress in refractive surgery patients. J Cataract Refract Surg 2002; 28: 1575–80.
24. Tauchen mit Einschränkungen In: Gesellschaft für Tauch- und Überdruckmedizin (GTÜM) e. V. und Österreichische Gesellschaft für Tauch- und Hyperbarmedizin (eds.): Checkliste Tauchtauglichkeit. Stuttgart: Gentner-Verlag 2014; 123.
25. Schnell D: Sportophtalmologische Aspekte des Tauchsports. Teil 2. Z Prakt Augenzheilkd 2003; 24: 27–34.
26. Schnell D: Sportophtalmologische Aspekte des Tauchsports. Teil 1. Z Prakt Augenzheilkd 2002; 23: 457–62.
27. Davies MJ, Fisher LH, Chegini S, Craig TJ: Asthma and the diver. Clin Rev Allergy Immunol 2005; 29: 131–8.
28. British Thoracic Society Fitness to Dive Group, Subgroup of the British Thoracic Society Standards of Care Committee. British Thoracic Society guidelines on respiratory aspects of fitness for diving. Thorax 2003; 58: 3–13.
29. Guaraldi P, Serra M, Barletta G, et al.: Cardiovascular changes during maximal breath-holding in elite divers. Clin Auton Res 2009; 19: 363–6.
30. Perini R, Gheza A, Moia C, Sponsiello N, Ferretti G: Cardiovascular time courses during prolonged immersed static apnoea. Eur J Appl Physiol 2010; 110: 277–83.
31. Breskovic T, Uglesic L, Zubin P, et al.: Cardiovascular changes during underwater static and dynamic breath-hold dives in trained divers. J Appl Physiol 2011; 111: 673–8.
32. Tauchtauglichkeit unter reisemedizinischen Aspekten. In: Gesellschaft für Tauch- und Überdruckmedizin (GTÜM) e.V. und Österreichische Gesellschaft für Tauch- und Hyperbarmedizin (eds.): Checkliste Tauchtauglichkeit. Stuttgart: Gentner-Verlag 2014: 135–9.
33. Taylor DM, O'Toole KS, Auble TE, Ryan CM, Sherman DR: The psychometric and cardiac effects of dimenhydrinate in the hyperbaric environment. Pharmacotherapy 2000; 20: 1051–4.
34. Gobbi F, Rossanese A, Buonfrate D, Angheben A, Postiglione C, Bisoffi Z: Epilepsy triggered by mefloquine in an adult traveler to Uganda. World J Clin Cases 2014; 2: 12–5.
35. van Riemsdijk MM, Sturkenboom MC, Pepplinkhuizen L, Stricker BH: Mefloquine increases the risk of serious psychiatric events during travel abroad: a nationwide case-control study in the Netherlands. J Clin Psychiatry 2005; 66: 199–204.
36. Buzzacott PL: The epidemiology of injury in scuba diving. Med Sport Sci 2012; 58: 57–79.
37. Vann RD, Butler FK, Mitchell SJ, Moon RE: Decompression illness. Lancet 2011; 377: 153–64.
38. Sykes O, Clark JE: Patent foramen ovale and scuba diving: a practical guide for physicians on when to refer for screening. Extrem Physiol Med 2013; 2: 10.
39. Torti SR, Billinger M, Schwerzmann M, et al.: Risk of decompression illness among 230 divers in relation to the presence and size of patent foramen ovale. Eur Heart J 2004; 25: 1014–20.
40. Ascending From A Dive. http://ehs.ucsb.edu/units/diving/dsp/forms/articles/Ascending.pdf (last accessed on 3 October 2014).

Corresponding author
Dr. med. Lars Eichhorn
Klinik und Poliklinik für Anästhesiologie und Operative Intensivmedizin
Universitätsklinikum Bonn (AöR)
Sigmund-Freud-Str. 25, 53127 Bonn, Germany
lars.eichhorn@ukb.uni-bonn.de

For eReferences please refer to:
www.aerzteblatt-international.de/ref0915

Case illustration:
www.aerzteblatt-international.de/15m0147

Further information on CME

This article has been certified by the North Rhine Academy for Postgraduate and Continuing Medical Education.

Deutsches Ärzteblatt provides certified continuing medical education (CME) in accordance with the requirements of the Medical Associations of the German federal states (Länder).

CME points of the Medical Associations can be acquired only through the Internet, not by mail or fax, by the use of the German version of the CME questionnaire. See the following website: **cme.aerzteblatt.de**.

Participants in the CME program can manage their CME points with their 15-digit "uniform CME number" (einheitliche Fortbildungsnummer, EFN).

The EFN must be entered in the appropriate field in the **cme.aerzteblatt.de** website under "meine Daten" ("my data"), or upon registration.

The EFN appears on each participant's CME certificate.

This CME unit can be accessed until 24 May 2015, and earlier CME units until the dates indicated:

– "Dry Eye" (issue 5/2015), until 26 April 2015;

– "Carpal Tunnel Syndrome" (issue 1–2/2015), until 29 March 2015;

– "Chronic Obstructive Pulmonary Disease" (issue 49/2014), until 1 March 2015.

Please answer the following questions to participate in our Continuing Medical Education program. Only one answer is possible per question. Please select the answer that is most appropriate.

Question 1

A diver holds his breath during ascent from a depth of 10 meters. How much has his lung volume changed by the time he reaches the surface?

a) +50%
b) +100%
c) +200%
d) –50%
e) –100%

Question 2

Which of the following can have a narcotizing effect during diving?

a) high partial pressure of nitrogen
b) mildly elevated nitrogen concentration
c) mildly elevated argon concentration
d) high partial pressure of helium
e) high partial pressure of xenon

Question 3

What type of heart disease is a relative contraindication for the attestation of fitness to dive?

a) a hemodynamically significant congenital heart defect
b) tachyarrhythmia caused by structural heart disease and requiring treatment
c) mitral stenosis with a valvular opening <1.5 cm²
d) a complex arrhythmia
e) a history of an acute coronary syndrome more than one year ago, with normal stress tolerance and good ventricular function at present

Question 4

What ear disease absolutely contraindicates diving?

a) incipient otitis externa
b) incomplete stenosis of the ear canal
c) acute dysfunction of the Eustachian tube so that pressure equalization is not possible
d) chronic dysfunction of the Eustachian tube so that the Valsalva maneuver is impaired
e) radical cavity formation (without dizziness or fall tendency on cold caloric testing)

Question 5

What drugs can divers take unproblematically?

a) antiemetic drugs
b) anticholinergic drugs
c) antipsychotic drugs
d) topical antifungal drugs
e) antimalarial drugs

Question 6

Which of the following is the appropriate initial treatment for decompression sickness?

a) avoid the administration of fluids (oral or intravenous)
b) immediate administration of 100% O_2
c) active warming of cold limbs
d) initial intubation and mechanical ventilation with PEEP in all cases
e) observation for 12 hours

Question 7

Decompression sickness can be triggered. Which of the following increases the risk of decompression sickness?

a) use of Nitrox
b) long intervals between consecutive dives
c) avoidance of frequent changes of depth (yo-yo dives)
d) good fluid balance
e) excessively rapid ascent from a dive

Question 8

Which of the following absolutely contraindicates diving?

a) age under 18 years
b) well-controlled asthma with normal stress tolerance
c) FEV_1/FVC <70% and FEV_1 <80% of norm
d) chronic bronchitis without obstruction
e) early COPD with good pulmonary function

Question 9

What is the main mechanism of diuresis in diving?

a) the Gauer–Henry reflex
b) the Frank–Starling mechanism
c) the Euler–Liljestrand mechanism
d) procalcitonin secretion
e) ADH deficiency

Question 10

Ear problems are common in divers. Which of the following pieces of advice is correct?

a) Persons who have sustained an episode of acute hearing loss should perform a rapid, powerful Valsalva maneuver before diving.
b) If there is edema of the ear canal, a single middle ear pressure equalization maneuver makes it possible to dive without problems.
c) Persons with chronic otitis media should prophylactically clean the external ear canal vigorously with cotton swabs once per day.
d) Persons with otitis should rinse the external ear regularly with alcohol-based solutions.
e) If aeration of the middle ear is at all impaired, do not dive.

CONTINUING MEDICAL EDUCATION

Diving Medicine in Clinical Practice

Lars Eichhorn, Dieter Leyk

eREFERENCES

e1. Schagatay E: Predicting performance in competitive apnoea diving. Part I: static apnoea. Diving Hyperb Med 2009; 39: 88–99.

e2. Lin YC, Lally DA, Moore TO, Hong SK: Physiological and conventional breath-hold breaking points. J Appl Physiol 1974; 37: 291–6.

e3. Lindholm P, Lundgren CE: Alveolar gas composition before and after maximal breath-holds in competitive divers. Undersea Hyperb Med 2006; 33: 463–7.

e4. Jost U: Spezielle Notfallmedizin – Ertrinkungsunfälle. In: Schröder S, Schneider-Bichel D (eds.): Wasserrettung und Notfallmedizin. Heidelberg: HJR-Verlag 2010; 116–7.

e5. Gesellschaft für Tauch- und Überdruckmedizin (GTÜM). www.gtuem.org/984/tauchmedizin/o2-mangel (last accessed on 30 September 2014).

e6. Muth CM, Rademacher P: Kurze Einführung in die Tauchphysik. In: Kompendium der Tauchmedizin. Köln: Deutscher Ärzte-Verlag 2006; 8–11.

e7. Fahlman A, Dromsky DM: Dehydration effects on the risk of severe decompression sickness in a swine model. Aviat Space Environ Med 2006; 77: 102–6.

e8. Nussinovitch M, Rimon A, Volovitz B, Raveh E, Prais D, Amir J: Cotton-tip applicators as a leading cause of otitis externa. Int J Pediatr Otorhinolaryngol 2004; 68: 433–5.

e9. Neher A, Nagl M, Scholtz AW: Otitis externa: etiology, diagnostic and therapy. HNO 2008; 56: 1067–79.

e10. Annual Diving Report – 2008 Edition. www.diversalertnetwork.org/medical/report/2008DANDivingReport.pdf (last accessed on 16 October 2014).

e11. Denoble PJ, Pollock NW, Vaithiyanathan P, Caruso JL, Dovenbarger JA, Vann RD: Scuba injury death rate among insured DAN members. Diving Hyperb Med 2008; 38: 182–8.

e12. Bennett PB, Marroni A, Cronje FJ, et al.: Effect of varying deep stop times and shallow stop times on precordial bubbles after dives to 25 msw (82 fsw). Undersea Hyperb Med 2007; 34: 399–406.

e13. Schweizerische Gesellschaft für Unterwasser- und Hyperbarmedizin (SUHMS): PFO Recommendations 2012. www.suhms.org/downloads/Flyers/PFO%20d%20Netz.pdf (last accessed on 10 February 2015).

CONTINUING MEDICAL EDUCATION

Diving Medicine in Clinical Practice

Lars Eichhorn, Dieter Leyk

Case illustration

A 49-year-old man (175 cm tall, with a body-mass index of 33) was somnolent on admission to the emergency department at 12 noon. He complained of persistent nausea and dizziness. Examination revealed left hemiparesis, with grade 3/5 strength in the upper limb and 4/5 in the lower limb. These manifestations had been present for about half an hour. Computed tomography (CT) of the head and chest revealed no abnormal findings, and the routine laboratory findings were normal as well. He related that he had been diving in an inland lake in the morning and had simulated multiple emergency ascents during rescue exercises. The symptoms had arisen while he was on the diving platform, a few minutes after the last emergency ascent exercise. The diving instructor thought he could not be suffering from decompression sickness, because he had not been diving any deeper than 8 meters.

Diagnosis and treatment

This patient's somnolence and other neurologic manifestations resulted from pulmonary barotrauma with ensuing arterial gas embolism to the brain/spinal cord. There was no pneumothorax requiring drainage, nor was there a pneumomediastinum. He was given 1 liter of colloid intravenously and transferred to a pressure-chamber center while breathing 100% O_2. After the first session in the chamber (according to US Navy Treatment Table 6, with maximal prolongation), his hemiparesis was markedly improved, but he continued to suffer from reduced drive, sensorimotor disturbances, and impaired concentration. After four further sessions over the next few days, he became asymptomatic.

Background

The fact that this patient had been diving just before the symptoms emerged suggests that a diving accident has taken place. The rapid drop in ambient pressure during the repeated emergency ascent exercises promoted pulmonary barotrauma, which can indeed occur even in dives of short duration to depths as little as 2 meters. If gas bubbles pass over into the arterial circulation, arterial gas embolism occurs, causing hemiparesis in this case. The symptoms typically arise within minutes of the diver's emergence from the water. Ischemia in the territory of an end artery is often not detectable on imaging studies (CT) in the first 24 hours.

▶ **Cite this as:**
Eichhorn L, Leyk D: Diving medicine in clinical practice. Dtsch Arztebl Int 2015; 112: 147–58.
DOI: 10.3238/arztebl.2015.0147

View publication stats